PSYCHOLOGICAL EFFECTS OF PROLONGED EXPOSURE TO SONAR SIGNALS AT AN ELEVATED INTENSITY
I. Five Days' Exposure to Signals at 85 dB

by

Benjamin B. Weybrew
and
Ernest M. Noddin

NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY
NAVAL SUBMARINE MEDICAL CENTER REPORT No. 689

Bureau of Medicine and Surgery, Navy Department
Research Work Unit MF12.524.004-9009DA5K.05

Reviewed and Approved by:

Charles F. Gell

Charles F. Gell, M.D., D.Sc.(Med.)
Scientific Director
NavSubMedRschLab

Reviewed and Approved by:

Joseph D Bloom.

J. D. Bloom, CDR MC USN
Officer-in-Charge
NavSubMedRschLab

Approved and Released by:

J. E. Stark

J. E. Stark, CAPT MC USN
COMMANDING OFFICER
Naval Submarine Medical Center

SUMMARY PAGE

THE PROBLEM

To ascertain what, if any, untoward psychological effects would occur in a situation in which twelve enlisted submariner candidates were continuously exposed for five days to a sonar signal at 85 dB.

FINDINGS

During the first 36 hours of the sound-on phase, errors in addition increased; letter cancellation errors first decreased then increased during the same time span. Personality test scores for Hostility, Depression, Anxiety, and General Maladjustive Trends increased the first 12 hours. All of these indices reverted to control levels 40 hours after the onset of the sound for all of the subjects except one man who developed anxiety symptoms sufficiently acute on the third exposure day to require analgesic-sedative medication.

APPLICATION

This pilot experiment provides some indication as to possible psychological effects to be expected in the crew of a submarine employing an active sonar system during long submerged cruises.

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit MF12.524.004-9009DA5K — Psychophysiological Effects of Prolonged Exposure to the Environment of the Submariner and Diver. It was approved for publication on 2 December 1971 and designated as Naval Submarine Medical Research Laboratory Report Number 689.

PUBLISHED BY THE NAVAL SUBMARINE MEDICAL CENTER

ABSTRACT

Twelve enlisted candidates for submarine training were confined to the Audition Laboratories of NAVSUBMEDRSCHLAB for a period of 10 days. Intervening between 2 pre-experimental and 2 recovery days were 5 days' exposure to a continuous sonar signal at 85 dB. Addition test scores declined, letter-cancellation accuracy also declined, and the four adjective checklist measures of affect and mood, viz., Hostility, Depression, Anxiety, and Maladjustive Trends, all increased within the first day of the sound exposure. However, these indicators had all reverted to pre-experimental level by 48-60 hours into the "sound-on" phase of the experiment. On the third day of the sound exposure one of the 12 subjects developed anxiety symptoms acute enough to warrant tranquilizer medication. Unfortunately, the self-control design of the study did not allow for any unequivocal statement regarding the cause of these symptoms.

TABLE OF CONTENTS

PSYCHOLOGICAL EFFECTS OF PROLONGED EXPOSURE TO SONAR SIGNALS AT AN ELEVATED INTENSITY

I. Five Days' Exposure to Signals at 85 dB

INTRODUCTION

This segment of the collaborative research effort of the staff of NAVSUBMEDRSCHLAB in the five-day sonar ping exposure study was directed toward an assessment of the psychological changes resulting from the exposure to the sonar sound in the context of the individual differences in the personalities of the men making up the subject sample. This focus therefore required a rather comprehensive study of the personality trait configurations of each subject prior to the experiment in order that each person's adjustment resources could be realistically appraised. Too, the particular measurement data collected daily during the sound exposure period must be sufficiently sensitive to subtle stress effects of this kind to validly indicate the adjustment status of the individuals in the group as the experiment progressed.

This paper presents the results of the first of two experiments involving the exposure of men to sonar signals at a somewhat elevated level of intensity. In a sense, the first study, with a 5-day sound exposure period may be construed as a pilot study for the second study wherein the duration of the sound exposure was 24 days, conducted at NAVSUBMEDRSCHLAB in the fall of 1971. The experiment discussed in this paper took place in the Auditory Testing spaces of the Naval Submarine Medical Research Laboratory from 26 October to 2 November 1970. The characteristics of the sonar signal used for the 5-day exposure period were 1 second pulses at 3.5 Kz and 85 dB introduced every 20 seconds. The sound was initiated at 1900 on the third pre-experimental (control) day.

METHOD AND PROCEDURE

Subjects

The subjects for this experiment were 12 nonrated enlisted Navy men who had volunteered for the experiment while awaiting Submarine School. The mean age of the group was 19 and their average aptitude test score approximated the 80th percentile for the Navy enlisted population as a whole. Based upon data obtained from the administration of a Psychiatric Screening Questionnaire, the PIB (Personal Inventory Barometer) (Weybrew & Youniss, 1958)[5] and the S.M.R.L. Biographical Inventory, (Noddin, 1969)[2] detailed background and personality information were compiled for each subject. These psychometric data were used first as a basis for assessment of the general adjustment status of each subject prior to the onset of the experiment and secondly, as a means of explaining some of the individual differences in response to the imposed stress as the study moved forward.

Measurement and Statistical Techniques

Based in some part upon past experience in measuring performance during simulated "pressure" dives, a battery of tests and measures was compiled with the following constraints in mind: (1) the measures should have acceptable face validity for intelligent young men used as subjects, (2) the test administration must be brief and unobtrusive; and finally, (3) the measures used must be sufficiently sensitive to show subtle effects of chronic but presumably low-level stress. Accordingly, an experimental measurement battery was compiled with these criteria in mind. Table I presents a brief description of each measure and Appendices A, B, and C present samples of the test materials.

TABLE I - MEASUREMENT BATTERY

Measure	Rationale	Description of Measurement Technique	Administration and Scoring Procedures
Addition[a]	Historically, arithmetical computation tasks have been demonstrated to be sensitive to mild stress.	Fifteen addition problems consisting of 11 digits, to be added horizontally by rows.	Time limit 2 minutes. Scores were the percentage of errors of the problems attempted. Instructions are to add by rows as rapidly as possible.
Multiple Affect Adjective Checklist (MACL)	The submarine literature suggests that changes in affect may be the most useful indicants of stress effects, (Weybrew, 1963).	The MACL consists of 132 adjectives factor analytically demonstrated to measure 3 traits: Anxiety, Depression, and Hostility.[b]	The respondent checks all adjectives describing his affective condition at the time. The 4 trait scores were obtained by summing the responses coincident with the keys provided for each trait dimension.

[a] The Addition and Letter Cancellation tests have been partially validated for use in stress experimentation, e.g., (Weybrew & Parker, 1968).

[b] The authors of the MACL are M. Zuckerman and B. Lubin, and it is published by Educational and Industrial Testing Service, San Diego, California. A second word list originating from the submarine literature was similarly validated with with the label, Maladjustive Trends, (Weybrew, 1963b).[4]

The Addition and Letter Cancellation tests were administered daily to all 12 Ss at approximately the same time i.e., about 10:30 a.m. The MACL, on the other hand, was collected two times each day, first in the a.m. after awakening and again just before retiring.

The arithmetical means for each measurement session during the 3-day pre-exposure, the 5-day experimental period and 2-day recovery time span were first plotted for each variable. The nonparametric technique, Wilcoxin Paired Replicates Test (Wilcoxin, 1945)[6] was then employed to test the reliability of differences between the measurement sessions for all of the variables. A minimally acceptable confidence level was set for the purpose of this study, at 5% (two tails), though in a few instances a 10% level was considered suggestive of a trend.

RESULTS

In the first place, it seemed plausible that because of possible interference effects of the sonar "ping" upon attentive processes particularly as they relate to problem solving, it appeared most likely that untoward effects would appear in the cognitive realm. The mean addition test scores presented as bar graphs plotted by measurement session in Fig. 1 bear on this point.

At the outset, it is to be noted that the mean number of single-digit prob-

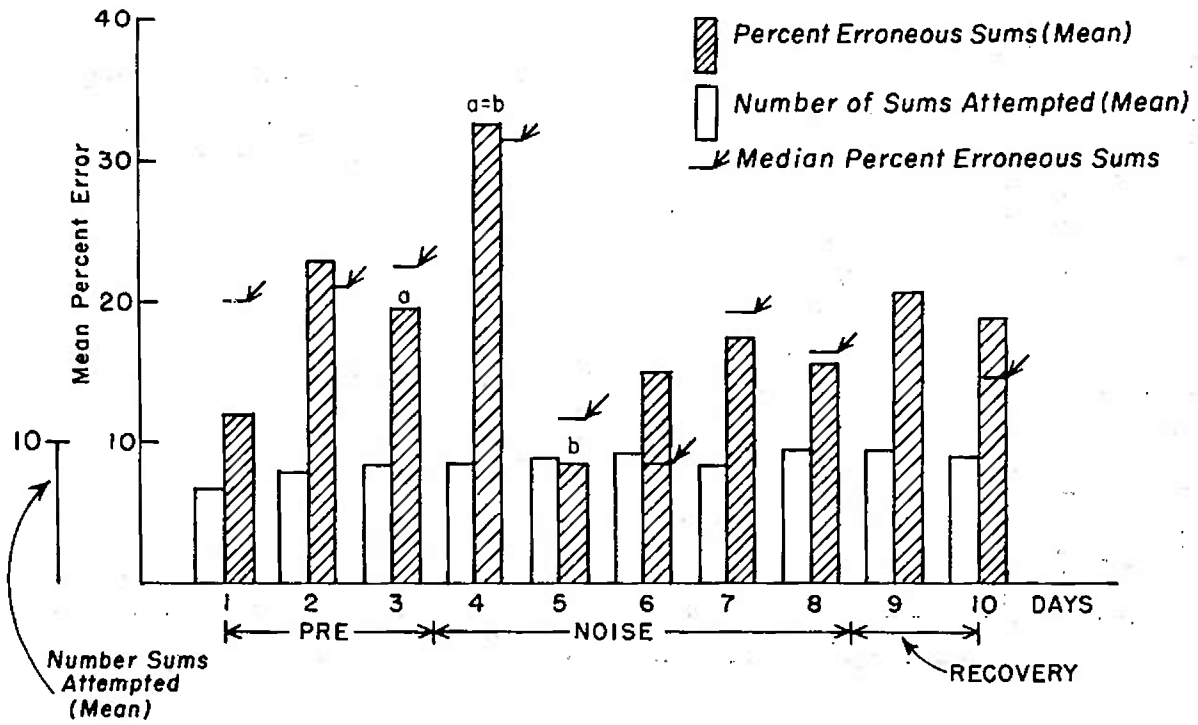

Fig. 1. Single-digit Addition Test Scores

lems attempted is relatively constant across all of the measurement sessions (days). With regard to the overall appearance of the arrays of mean percentage errors, it is important to notice the relative symmetry of the distributions as adjudged by the essential coincidence of the medians and means for each session. As to the effects of the introduction of the sonar signal, it is seen that between session 3 and 4, the mean addition errors increased approximately 14 hours after the onset of the sound from 20% to 32%, a difference significant at the 10% level. However, at about 1100 on the 5th day (about 38 hours after the sound was turned on) the mean addition error score had reverted to a level below that of the pre-experimental control period (5% confidence level). Whereas, subsequent mean variations appeared in Fig. 1 to be substantial, nevertheless none of the between-sessions differences reached the 10% confidence criterion.

The effects of the sonar "pings" upon sequential reaction time and eye-hand coordination may be inferred from an examination of the Cancellation Test scores plotted as a line graph in Fig. 2.

It is immediately evident from the graphs in Fig. 2 that the pre-experimental period had not stabilized when the sonar "ping" was introduced on the 3rd day of the study. As a result, the drop in percentage discrimination errors the first 15 hours may be construed as a continuation of the learning curve observed in the pre-experimental phase. However, the data for the sec-

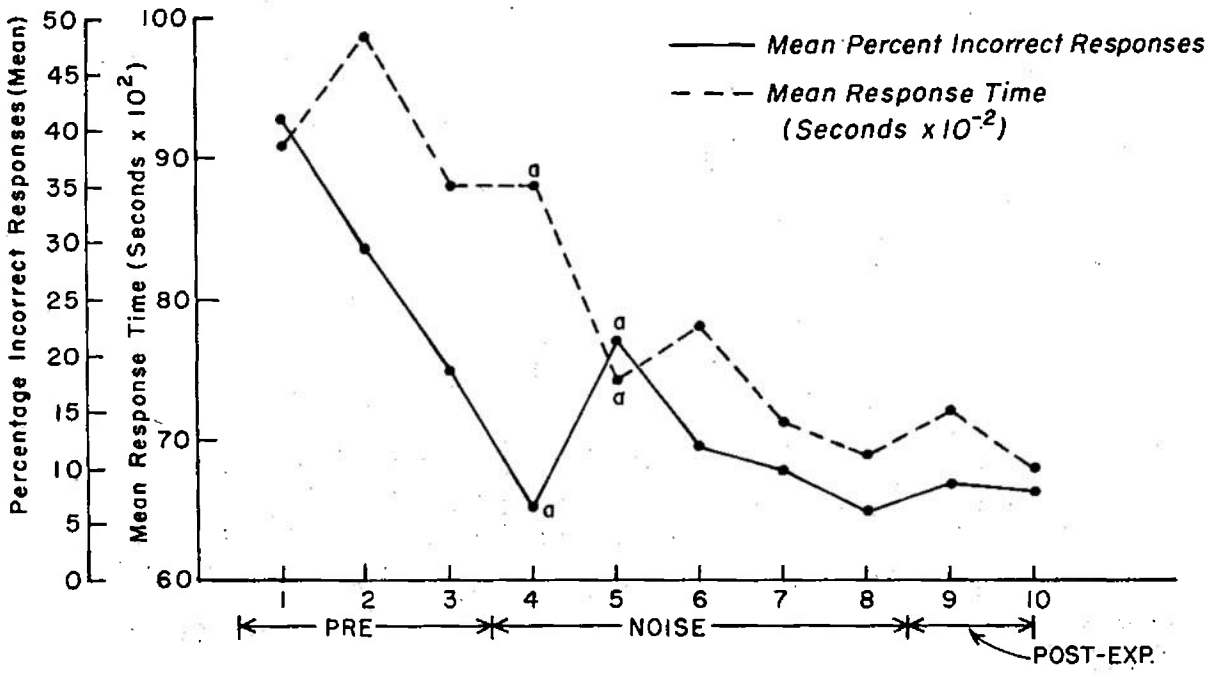

Fig. 2. Letter Cancellation Test Scores

ond day of the "sound-on" period suggests that the reaction time decreased but with a concomitant "cost" of increase in error rate. The curves for both the mean error and reaction time scores depict a rather typical learning curve. Certainly after 36 hours exposure (Day 5, in Fig. 1) there is no evidence whatsoever for any interference effect of the sound or any other aspect of the confined conditions.

The literature of Submarine Psychology, e.g., (Weybrew, 1963b)[4] suggests the relevance of subjective ratings as a method for the periodic assessment of the general adjustment status of submariners during prolonged, submerged missions. As suggested in the procedural section of this paper, it seemed a plausible assumption that subjective symptomatology as obtained by the modified MACL (Multiple Adjective Checklist) would be a usefully reliable indicator of the overall adjustment of a group of submariners confined to the kind of environmental conditions maintained during this study. The modified MACL mean subtest scores are plotted in Fig. 3.

As indicated in the procedural section of this paper, the MACL data were collected twice daily, before retiring at night and an hour or so after arising, in most instances after breakfast. Ac-

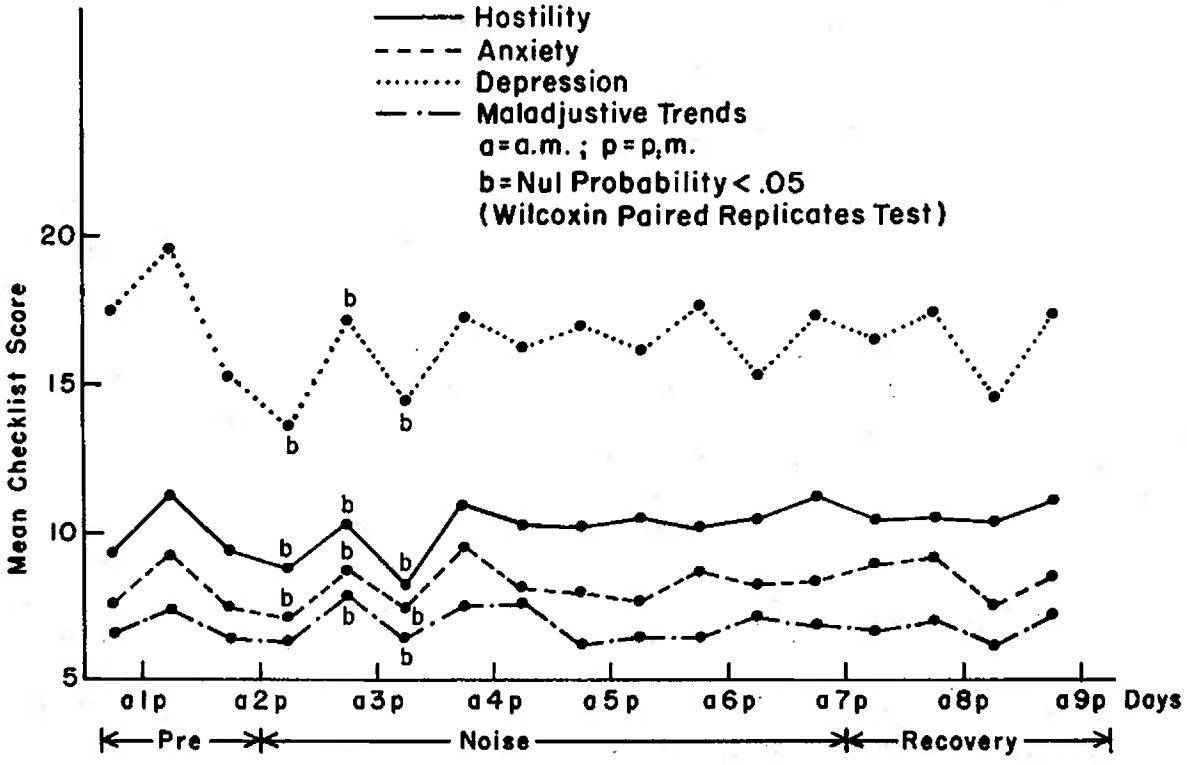

Fig. 3. Adjective Checklist Scores

cordingly, it is to be noted that the mean scores for each of the four subtests are plotted both for the p.m. and a.m. of each day, these data points presumably coinciding with a fatigued state and an alerted or rested state, respectively.

First, looking at the plots for the subjective data, it is seen in Fig. 3 that the p.m. measures taken on day 2 (about 16 hours after onset of the sound) showed no significant change. In contrast, however, a significant change (5% confidence level) is seen in Hostility, Anxiety, Depression, and Maladjustive Trends subtests for the subsequent 3 data points. Quite possibly of importance to note is the direction of change, that is, all scores increased the morning after the first regular sleep period (a.m. on day 3), dropped by night, and rose again by a.m. on day 4. It was not until the 3rd morning in the sound-on condition, 72 hours after the onset of the "ping", that there was no increase in scores in comparing p.m. with a.m. scores. These findings suggest that the sound may interfere with the quality and quantity of the men's sleep for about 2 nights or about 60 hrs. exposure in the present study. Since the curves in Fig. 3 show no statistically significant fluctuations (except for the Depression Score) subsequent to the a.m. data collection on Day 4 (48 hours after sound onset), it is assumed that adaptation to the sound had occurred at that point for most subjects.

Without question the Depression score showed the most between-session variability. Also, although the subtest scores are in raw score form and hence are not directly comparable, nonetheless it appears that this score may represent the most sensitive test of the battery used in this study. It is the only test of the battery showing significant a.m./p.m. fluctuations (high in a.m., low in p.m.) following the 48-60 hour adaptation period. There are several possible explanations for these data, all involving the meaning of Depression as a complex motivational-affective parameter as compared to the other three scores whose content is first and foremost affective in nature. Suffice it to say that it appears that Depression as measured by the MACL, is probably "tapping" processes closely related to "boredom", negative attitudes toward the study and the like. As a result, this score would appear to have potential as a concomitant, possibly causally related, to performance on a number of tests and measures administered by other branches of the NAVSUBMEDRSCHLAB collaborating in the study.

Additional data were obtained from brief daily interviews and from the debriefing interview with each of the men. Though admittedly somewhat gross, this information nonetheless may be indicative of possible psychological trends of some relevance. For example, some form of "tinnitus aurium" was reported sometime during the experiment by 6 men (out of 12). Likewise, an equal number reported one or more headaches of varying severity and duration during the study. Possibly to be expected is the fact that all of the subjects reported the tasks became increasingly boring as the study progressed. This was particularly true for one test (Yellow Submarine). Additional interview data were: Ear pain, 2 Ss;

increased tension, 2 Ss; excessive group irritability, 2 Ss, periodic difficulty getting to sleep, 4 Ss; and undiagnosed febrile conditions, 2 Ss. One 21 year old, 3rd class petty officer (Subject "N"), who had been tentatively accepted as a candidate for the Submarine Service after 1 1/2 years sea duty on a surface craft, began having considerable difficulty sleeping the 3rd night of the sound-on phase of the study. Concomitantly, his anxiety level increased markedly and the next day he developed what he called a migraine headache, but which the clinical staff in private agreed was a rather typical "tension headache" of moderate severity. Three Darvon (Lilly) pulvules taken the 3rd experimental day failed to produce relief, so the duty Medical Officer prescribed Fiorinal (Sandoz) 2 tablets on the 4th day and 4 tablets on the 5th experimental day (Maximum recommended daily dosage 6 tablets), before relief was obtained on the first post-experimental or recovery day. It should be noted that the personality test data clearly indicated that "N" was, at best, extremely emotionally unstable prior to the study. For example, his test score indicating an Anxiety Neurotic Disorder of some kind were at the 99th percentile and his Depression Tendencies score at the 95 percentile. As a result, a reasonable explanation of the symptomatology that appeared in this young man during the sound exposure was the appearance of a somatization component of a chronic neurotic disorder. The fact that this man was subsequently disqualified for the Submarine Service by reason of this psychopathology tends to confirm this interpretation. However, in the absence of control data obtained from a matched group, similarly confined but not exposed to sound*, it cannot be unequivocally stated that the sound exposure or confinement or deprivation or all three plus other factors did or did not cause these symptoms. It is the senior author's opinion that this incident involving one subject demonstrated to an extent the importance of implementing a psychiatric screening procedure somewhat like the one used in this study so that should maladjustive trends occur there will be available data contributing toward an understanding of the nature of these changes on an individual basis.

SUMMARY AND DISCUSSION

Prior to the experiment, the 12 Navy enlisted men who had volunteered as subjects for this study were administered the standard submariner psychiatric screening battery which included a biographical inventory, 2 measures of motivation, a measure of depression-proneness, and a test of general emotionality. Thus, the day-to-day measures obtained during the 5-day sound exposure period were interpreted in the context of the personality differences delineated by this battery.

While the impression is that there were no acutely maladjustive trends observed in the personality data (with the exception of one man), there were nonetheless some psychological changes which, while not thought to be debilitative, may be worth noting. These changes moreover, while not necessarily causally related to the sound,

**Ideally, a third group, neither confined nor exposed to sound would be desirable as a control for confinement effects per se.*

were nonetheless coincident with its onset. These were as follows: (1) Accuracy of adding single-digits declined (10% confidence level); (2) Letter cancellation errors first decreased, then increased (5% level) 36 hours into the exposure phase; (3) sequential reaction time scores from the same test remained constant the first 15 hours, then decreased (1% level) the second "sound-on" day; and (4) Subjective symptomatology as measured by the MACL (Mood Adjective Checklist) suggested that during the first 12-hours of sound exposure Hostility, Depression, Anxiety, and general Maladjustive Trends all increased (5% level). One pervading problem in interpreting these data, in particular the performance scores, had to do with the difficulties of separating the effects of learning from the confounded effects of sound exposure, confinement to list a few of the factors involved.

Possibly the most important overall finding of this pilot study was that all of these changes had reverted to the control or pre-experimental level when the data were again collected approximately 36 hours into the exposure period. At that time also, it was noted that the mean sequential reaction time had increased significantly (0.1% level). No statistically significant fluctuations of the means for any of the variables were observed during the remaining 3 experimental and 2 post-experimental (recovery) days. Taken together, the finding that most adjustment indices declined at the outset of the sound exposure period, then reverted to pre-experimental levels 24-36 hours afterwards (a finding corroborated by the post-experiment debriefing interview data) suggests that a time span of 24-36 hours may be required for optimal adaptation to sound-stress of this kind.

The data from the daily interviews and from the post-experimental debriefing interview provided some indication that rather benign symptoms, such as excessive tension, interpersonal irritability, headaches, ringing ears, and minor sleep problems did occur in some Ss from time to time during the experiments. While none of these symptoms were considered debilitative in any sense, one of the 12 enlisted men on the 3rd day of the "sound-on" phase developed anxiety symptoms sufficiently acute to require analgesic-sedative medication. Whereas, it is not believed that the sound exposure, confinement and/or deprivation directly caused these symptoms, the experimental design does not justify a definitive statement in this regard.

REFERENCES

1. Mann, H. B. & Whitney, D. R. (1947). On a test of whether one of two random variables is statistically larger than the other. Annals of Mathematical Statistics, 18, 50-60.

2. Noddin, E. M. (1969) The relationship of background variables to attrition in basic enlisted submarine school students. NSMRL Rpt. 597.

3. Weybrew, B. B. (1963a) Autonomic resiliency subjective symptomatology and submarine stress. NSMRL Memo. Report 63-13.

4. Weybrew, B. B. (1963b) Psychological problems of prolonged periods of marine submergence. In Burns, N., Chambers, R. & Hendler, E. (Edits) Unusual Environments and Human Behavior, Glencoe, Ill.: Free Press.

5. Weybrew, B. B. & Youniss, R. P. (1958) The personal inventory barometer (PIB): I. Development of the questionnaire. NSMRL Rpt. 290.

6. Wilcoxin, F. (1945) Individual comparisons by ranking methods. Biometrics Bull., 1, 80-83.

APPENDIX A

ADDITION PROBLEMS

Instructions: Each row of numbers is an addition problem. Add from left to right as fast as you can and put the sum in the blank on the right. Work rapidly for ____ minutes. You are not necessarily expected to finish all of the problems. Please note the time then start.

8	9	2	4	6	8	3	3	0	3	4
8	1	1	8	2	1	9	4	3	7	5
8	9	9	1	1	2	2	2	8	2	1
9	6	9	6	2	5	6	2	1	7	7
1	3	4	9	4	2	6	6	4	2	2
8	9	9	8	7	8	9	6	1	9	6
6	4	2	3	3	6	3	6	4	4	0
4	6	4	7	2	9	5	7	0	9	2
1	1	5	1	5	4	9	1	5	6	4
8	6	3	6	4	6	4	7	3	3	7
2	5	3	9	1	6	9	5	1	5	0
9	9	4	3	5	6	6	9	5	9	3
6	8	3	4	2	9	9	4	9	5	2
1	2	5	2	7	9	4	6	7	7	8
9	3	6	6	3	6	4	9	5	8	8

APPENDIX B

CANCELLATION TEST

Group

Series 30
Time___

Instructions: Below are listed a series of capital O's with capital C's interspersed. The task is to work from left to right making a mark through each C. Work as fast as you can for 1 minute. You are not necessarily expected to finish. However, should you finish, please record on the sheet exactly the time taken.

OOOOOOOOCCOOOOOOOCCCOOOOOCOOCOOOOOCOCOOO

OCOOCOOOOOOOOOOOOCOOOOOOOOCOOCOOCOOOOO

OOCOOOOOOOOCOCOOOOCOCOOOOCOOOOOOOOOCOOO

OOOOCOOOOOOOOOOOOOOOCOOOOOOOOOOOOCOOOO

OOOOOOOOOOCOOOOOOCOOOCOOOOOOOOOOOOOOCO

OCOOOOCOOOCCOOOOOCOOCOOOOOOOOOOOCOCOOOO

OOOOOOOOOOCOOOOOCOCCOOOOOOOOOOOOOOOOOC

OOOOOOOOOCOOOCOOOOOOOOOOOOOOOOOOOOOOOO

OCCOOOOCOOOCCOOCOOCOOOOOOOOCCOOOCOOOOOO

OOOOOOOOCOOOOOOOOOOOOOOOCOOOOOOOOOCOOOO

COOCCOOOOOOOOOOOOCCCOOOOCCOCOOOOOOOOOOO

OOOOOOOOCCOOOOOCOOOOOOOOOCOOCOOOOOOCOOOO

OOOOOOOOCOOOOCCOOOOOOOCOCOCOOOOCOOOOOCO

OOOOCOOOCOOCOOOOOOOOOCOOOOOOOOOOOOOOOO

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
NAVAL SUBMARINE MEDICAL CENTER, Naval Submarine Medical Research Laboratory	Unclassified
	2b. GROUP

3. REPORT TITLE

PSYCHOLOGICAL EFFECTS OF PROLONGED EXPOSURE TO SONAR SIGNALS AT AN ELEVATED INTENSITY I. Five Days' Exposure to Signals at 85 dB

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Interim report

5. AUTHOR(S) (First name, middle initial, last name)

Benjamin B. WEYBREW, Ph. D. and Ernest M. NODDIN

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
2 December 1971	11	6

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. MF12.524.004-9009DA5K	NSMRL Report Number 689
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Naval Submarine Medical Center Box 600 Naval Submarine Base Groton, Connecticut 06340

13. ABSTRACT

Twelve enlisted submariner candidates were confined to the Audiology Laboratories of NavSubMedRschLab for a period of 10 days. Intervening between 2 pre-experimental and 2 recovery days were 5 days' exposure to a continuous sonar signal at 85 dB. Addition test scores declined, letter cancellation accuracy also declined, and the four adjective checklist measures of affect and mood, viz., Hostility, Depression, Anxiety and Maladjustive Trends, all increased within the first day of the sound exposure. However, these indicators had all reverted to pre-experimental level by 48-60 hours into the "sound-on" phase of the experiment. On the third day of the sound exposure one of the 12 subjects developed anxiety symptoms acute enough to warrant tranquilizer medication. Unfortunately, the self-control design of the study did not allow for any unequivocal statement regarding the cause of these symptoms.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Sonar habitability in submarines						